indicated with some certainty by the comparison of photographic and photovisual magnitudes, it is of interest to find it appearing as the result of an entirely different method of investigation.

The absence of faint white stars is known to be a characteristic of other regions as well,[3] but it must not be inferred that such objects are not to be found anywhere in the sky. In Selected Area No. 88, for example, in one of the outlying clouds of the Milky Way, photographs by the exposure-ratio method indicate that the stars of the 14th or 15th magnitude are nearly normal in color and thus include a considerable number of objects that are white. Mr. Shapley has also accumulated evidence of this sort in connection with his study of clusters.

[1] These PROCEEDINGS **2,** 1916, (521–525).

[2] *Astroph. J., Chicago, Ill.,* **39,** 1914, (361–369); [*Mt. Wilson Contrib.,* No. 81].

[3] *Ibid.,* **40,** 1914, (187–204), **42,** 1915, (92–119), (120–132); [*Mt. Wilson Contrib.,* Nos. 83, 100, 102].

TERRACING OF BAJADA BELTS

By Charles Keyes

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For the local stream-trenching and the resultant terracing of the higher zones of those long uniform slopes which so often spread out from the foot of desert mountain ranges there is an explanation very much simpler than any of the numerous ones yet offered. It has the advantage of being in strict accord with the regular and ordinary phases of erosional action which recent critical observation shows to be now at work as vigorously and as effectively as they have been in any past period. It is, in effect, nothing more than a reiteration, in a somewhat new form to be sure, of the old law of parsimony which forbids the unnecessary multiplication of explanatory elements and agencies.

In all late physiographical writings in which the term bajada is used it is unfortunately misconstrued. Spanish-speaking Americans do not seem ever to have given the title so broad a meaning as that sometimes attached to it. If the name is to remain a useful geographical term of description it should be allowed to retain something of its original significance, and should be restricted in its application to the steeper slopes of the desert piedmonts. Without exception bolsons appear to present four distinct physiographic areas, or belts, three of which are plains. There is the central, more or less level tract, sometimes covered for a period of a few days or weeks of each year by a

thin sheet of gathered storm-waters—the *playa*. There is next the long smooth slope of low inclination, having about a 2% gradient. This is followed by a short, steeper slope, with a 4% grade, to which the name *bajada* is properly given. Fourth is the mountainous periphery.

In the literature on the arid regions the bajada-belt is usually treated as one of the most conspicuous and important drainage features, as formed by prodigious outwash from the peripheral highlands of basins of centripetal drainage, and as consisting of a series of great coalescing delta-fans. To this interpretation several strong objections arise. Discordant facts greatly outweigh the supporting evidence. The piedmonts of western deserts most frequently described chance to be on the margins of the Great Basin where the lofty Wasatch range and the still loftier Sierra Nevada produce effects which are not at all typical of the true Basin-ranges. In other places the steeper parts of the intermont plains, or bajadas, often mark belts of resistant rocks and are almost devoid of soil. In still other cases the extension of the even-sloping bajadas up into the valleys of mountain-arroyos is manifestly the direct result of rapid and tremendous drifting of soils from the lowland plains, rather than of the gravitational flow of detrital materials from the adjacent highlands. The volume of finer rock-waste brought down from a desert-range by the infrequent storm-waters is not by any means what might be expected; it is, in reality, phenomenally small. As more fully stated elsewhere the yearly amount washed down by the rains may be swept away by the winds in a single day.

In spite of the fact, then, that the *bajada* is often a belt of thick, adobe soils, of drifting sands, or of sporadic outwash from the nearby mountains, it is also still oftener true that it is an area of the most indurated rock, so free from soil that, as W. J. McGee describes, "the horses' shoes beat on the planed granite, and schist and other hard rocks in traversing the plain 3 or 5 miles from the mountains." Then, again, there are typical bajadas widely separated from desert ranges by deep longitudinal valleys which hug the mountain bases—conditions under which there is no possible chance for the outwash from the highland to reach the plain. The Sandia, Manzano and Caballos sierras, in central New Mexico, are a few of the many notable examples.

The terracing of arroya-courses in the piedmont belt appears usually to be merely the outcome of a vigorous contest which is constantly waged between the local, temporary aggrading of wind-driven soils or sands on the one hand, and on the other hand by the weak degrading action of the infrequently running mountain torrent. The phenomena of bajada-terracing is not, as urged by some physiographers, a necessary

consequence of the general lowering of the highlands by stream-action, while the intermont lowlands are being filled up; because some of the best examples of terracing border broad plains having rock-floors. For the same reason it does not appear possible that there ever occurs during so-called topographic maturity an adjustment by water action between one bolson and an adjacent lower one which results in the terracing of the higher. There is little or no actual evidence to show that bajadas were all formed during periods of glaciation; since some of the most typical expressions of these sloping plains are found surrounding low knolls near sea-level, and far below all possible altitudes of glacial action in the region. Neither does it appear likely that bajadas were built up during interglacial epochs of materials which accumulated in the mountains when the latter were covered with ice; for this does not explain the many cases in which rock-floors are present. Nor is it any better to postulate a recent increase of temperature and a different distribution and amount of rain-fall abetted by the advancement of the area in the geographic cycle; for terracing is now going on before our very eyes at an astonishingly rapid rate, and as quickly is it also completely obliterated. In many localities over-grazing is manifestly a potent and direct cause of the tremendous recent trenching and corrading by sporadic storm-waters of the soft temporary soil accumulations in the desert.

In recently setting forth reasons for believing that the gradational effects displayed by the intermont plains of arid regions are mainly accomplished by means of the winds, I have attempted to point out the fact that the action takes place chiefly uphill instead of gravitationally down-stream as in the case of running waters. I have also endeavored to emphasize the point that the relatively steep slope of the bajada-belt represents the highest possible wind-gradients, just as the river-bed in a peneplain approaches the lowest possible water-gradient. This statement appears to be amply supported by the results arising from the artificial diversion of arroyo-courses over the smooth bajadas.

Were the leveling tendencies of the winds wholly absent from the desert regions it is quite possible that the corrasive effects of what desert waters there are would be much the same as they are in humid lands, differing only in degree. This is well shown in the cases of wing-dams that have been constructed to protect lines of railway from the disasters of the flood-sheet and the latter has come before the earth-works have had time to be leveled by the winds. In one instance in particular the culvert and track were washed out in less than an hour's time, and a canyon, 75 feet deep, 50 feet wide and several miles long,

was excavated in the smooth surface of the sloping plain. By the time a permanent bridge was built to span the deep trench the winds had filled the entire excavation, so that where a yawning chasm had been was again as smooth as the rest of the plain, and the wing-dams also had melted down into the general evenness of the desert's surface. For several years, until it was finally replaced by an earthen grade, travelers were wont to express great wonderment at the possible utility of so fine a steel bridge resting on the smooth sands of the desert plain.

The Socorro arroyo, in central New Mexico, presents another pertinent case. There is water running in the shallow wash once or twice a year, the supply coming off the lofty Magdalena peak 20 miles away. For many years this arroyo, which divides the town of the same name, has given the residents an infinite amount of trouble. That its 2% grade really produces torrential conditions when the waters do run is indicated by the fact that the arroyo-bed is composed largely of pebbles and boulders, many of the latter attaining a size of 2 feet. In order to obviate the yearly inconveniences of flooding it was determined, a few years ago, to divert the channel 4 miles above the town. This change of course was accomplished by cutting a narrow trench from the bed of the water-way through its bank to a point some 50 yards to one side, where the general plain was slightly lower than the bed of the wash at the head of the ditch. A low dam was thrown up obliquely across the arroyo by piling up boulders from the bed. The theory was that the first water coming down the wash would flow out the ditch, or spill-way, and there would soon cut a deep channel; and that eventually this would carry away all of the future flood-waters. Results more than fulfilled expectations. The first time the dry creek became a brook there was trenched in a single night a chasm 50 feet deep for a distance of more than a mile down the slope of the plain. The materials from the great artificial canyon spread out over the railroad tracks 3 miles away to a depth of 7 feet and to a width of half a mile, necessitating the rebuilding and raising of the grade for a distance of several miles. These two illustrations might be infinitely repeated.

Observations such as these demonstrate beyond a shadow of doubt that whenever around the desert ranges there are alluvial fans, or accumulations of unindurated deposits, it is possible at any time for profound and rapid dissection to take place through means of the copious but infrequent storm-waters. The recent notes of C. L. Baker, A. C. Trowbridge and others on the eastern slopes of the Sierra Nevada, amply confirm these conclusions. Since, however, the restricted areas in which the latter investigations were undertaken lie at the foot of

lofty ranges and border a region of moister climate the action of running waters is more nearly normal than in the Great Basin proper. Yet, in the interior of the latter the same phenomena are also well displayed. Around the southern rim of one remarkable desiccated Las Vegas, in southern Nevada, in the low Spring, Newberry and Eldorado ranges, the bajada is frequently dissected and terraced in a singular manner. So extensive is it that it may be clearly distinguished even at a distance of 10 or a dozen miles. Dissection and terracing are also everywhere apparent around the region of the excessively dry basins of Death valley, the Armagosa plains and the Mojave desert.

In this connection there is one circumstance which not only A. C. Trowbridge and C. L. Baker appear to have overlooked, but likewise F. L. Hess, J. E. Spurr, G. K. Gilbert, H. W. Fairbanks and other earlier writers. In the descriptions of the terrestrial deposits the origin of the latter is ascribed entirely to water-action. No account seemingly is taken of possible assistance of wind-action in piling up locally these masses of debris. Photographs of the region, which the authors named reproduce, display unmistakable signs of plenty of windwork. On this point direct personal observation is even more conclusive. In the building up of the so-called alluvial fans and of the bajada when composed of fine materials the winds appear to be the controlling power. Arroyo-waters seem mainly to be merely modifying agents, supplying some coarse rock-waste from the mountains, but largely locally turning back the materials brought in up-grade from the lowland plains. The effects simulate the alluvial fans of humid regions; but they are not by any means their exact counterpart.

After the lower reaches of the canyons, immediately before they debouch upon the plains, become over-filled in the course of a few months or a few years, with the wind-driven sands and dusts and are eolicly aggraded they are readily dissected and even terraced by the first appearance of heavy storm-waters on the mountains. For accomplishing these results the time-element is certainly not so interminably long as has been commonly supposed. It is not necessary to stretch it back to the Glacial period, and far beyond. It is not to be gauged by tens of millenia. Its span is to be measured not even by years, but by months or weeks. It is known to have been limited by a single rising and setting of the sun.

The local dissection and terracing of the so-called alluvial fans in arid regions may have a significance still broader than that commonly ascribed to it. In the explanation of these phenomena we may have the key to the specific method by which general leveling and lowering of

desert lands are accomplished. Neither feature is confined to areas which are situated at the mouths of canyons. Both are displayed in bajada belts where rock-floors are present and where the once even surfaces are worn out on the beveled edges of tilted strata. The Calico range, in the Mojave desert, north of Daggett, California, is a notable but not an isolated example. No eminence of the Great Basin region appears, at first glance, to be more certainly a 'lost mountain,' a lofty range buried up to its shoulders in its own debris. The bajadas on either side of the ridge all but meet over its summit. So low and rounded is the crest that manifestly there is no opportunity for extensive outwash around the borders. There is, in this instance, not only remarkable dissection of the bajada belt taking place at the present time but a widening of the apparent lines of drainage into wide flat-bottomed esplanades with deep reentrants. Elsewhere there is the anomaly of a long sinuous terrace several hundreds of feet in height separating the higher general plains-surface from the lower local plains-level. In this we get a glimpse of the formation of those heretofore inexplicable but characteristic desert features known as plateau-plains. In their last stage the isolated Tówa-yal-lané, Acoma and Chupadera mesas, of New Mexico, are conspicuous illustrations. To this phase of the problem attention is later turned.

The feature of desert bajada-terracing, when explained upon a strictly aqueous basis, cannot but lead to complete misinterpretation. The phenomenon has no necessary connection with former and greater stream-activity. It is one of the wide-spread characteristics of desert lands. It is far more largely the result of wind-action than of water-action. Its marvellous aspect is the great rapidity with which it takes form. It is, in reality, one of the subordinate expressions of regional eolation.

RELATION OF THE APEX OF SOLAR MOTION TO PROPER MOTION AND ON THE CAUSE OF THE DIFFERENCES OF ITS POSITION FROM RADIAL VELOCITIES AND PROPER MOTIONS

By C. D. Perrine

OBSERVATORIO NACIONAL ARGENTINO, CÓRDOBA

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Continuing the investigation of the apparent dependence of the position of the solar apex upon proper motion as derived from radial velocities,[1] apices have now been derived from the proper motions